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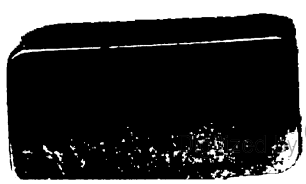
AN INVESTIGATION AND DEVELOPMENT
OF A WATER POWER PROJECT ON
THE FLAMBEAU RIVER NEAR
LADYSMITH, WIS.





# AN INVESTIGATION AND DEVELOPMENT OF A WATER POWER PROJECT ON THE FLAMBEAU RIVER NEAR LADYSMITH, WIS.

BY

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AND

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-I--N--D--E--X-

## LOCATION

The proposed hydro-electric development considered in this report is to be constructed at Big Falls on the Flambeau River in Rusk County, Wisconsin, near the village of Ladysmith. The site is in the northwestern part of the state near the juncture of the Flambeau and Chippewa rivers. No towns of appreciable size are situated in this vicinity, the closest town of over 10,000 population being Ashland, Wis., which is about 90 miles north of the proposed site.

## FLAMBEAU RIVER

### Drainage Area

The drainage area of the Flambeau River lies in the northern part of Wisconsin within the glaciated area, which contains many small lakes and watercourses. The river flows southwest into the Chippewa River, the juncture being in the southern part of Rusk County. This area includes 2120 sq. mi. with an extreme length of 81 miles, and an average width of 27 miles. A map of the drainage area is shown in Plate I.

### Maximum and Minimum Discharge of the Flambeau River:

The data upon which the discharge of the Flambeau River was determined was taken at Ladysmith, Wis., by the United States Geological Survey. The gauging station was established in 1903 and was discontinued in 1906 giving complete readings for four years. The data was taken from "Progress of Stream Measurements" for the above years. This data gave the gauge

height at the station or point of observation, in feet. A rating table accompanying the observations gave the discharge in cubic feet per second corresponding to the different heights of the gauge. These discharges expressed in cubic feet per second were reduced to cubic feet per square mile of drainage area by dividing by the size of the drainage area or 2120 sq. mi. It was found by a study of this data that the year 1904 was the year of minimum discharge and 1906 that of maximum discharge for the years for which such data was available.

For these maximum and minimum years of 1906 and 1904 hydrographs were plotted. These hydrographs are curves on which the horizontal scale represents time subdivided into months and from this scale any day in the year can be located. The vertical scale represents the flow as computed in cubic feet per second per square mile of drainage area for each day of the year. Therefore, from these hydrographs the flow of the river for any day of the year in question can be determined by reading the discharge as plotted and multiplying the flow so determined by the number of square miles of drainage area above the station. These curves also show the variation of the discharge for any period of time. These curves are shown on Plates II and III.

For the minimum year of 1904, a duration curve was plotted. This curve shows for the given year the number of days on which a given discharge was noted. This curve was plotted to the same horizontal and vertical scales as the hydrographs, and is shown in Plate II. For example: if one cubic foot per second per

square mile of drainage area is required, the curve shows the number of days on which this or a larger discharge took place. Therefore, the curve shows the duration of any given flow.

Rainfall

The primary source of stream flow is, of course, the rainfall and a direct relation exists between the two, but there is no direct proportion which this relation follows; however, a careful examination of rainfall records together with the stream flow data tends to establish this proportion for the particular drainage area in question. Therefore, a study of the rainfall records will give a general understanding of the the flow of the Flambeau River when examined in connection with the hydrographs, and will give an indication of the relation of rainfall to run-off to be expected in the future.

The monthly rainfall was figured for the following government stations on or near the drainage area:

| | |
|---|---|
| Ashland | Prentice |
| Barron | Medford |
| Butternut | Weyerhauser, |
| Hayward | Appollonia |
| Ladysmith | |

The average for each month for all these stations was taken from 1889 to 1913 as far as the government data was complete. This data is included in Appendix A. The results were plotted using inches of rainfall as the vertical scale and months as the horizontal scale. These curves show the average monthly rainfall over the entire drainage area, and are shown in Plates IV to VII inclusive.

The daily rainfall for the same stations on the drainage area was figured and was successively added giving the cumulative rainfall to date for each day of the minimum year. This data is shown in Appendix B. Then with the day of the year as the horizontal scale and inches of rainfall as the vertical scale, the daily cumulative rainfall was plotted, and is shown in Plate VIII. This curve shows for any given date the total amount of rainfall during the year up to that day.

From the hydrograph shown in Plate II, the daily discharge of the river in cubic feet per second per square mile was taken. Knowing the size of the drainage area, this was reduced to depth of discharge in inches over the drainage area. These amounts were successively added giving a cumulative discharge in inches. This curve was plotted to the same co-ordinates or scales as the cumulative rainfall curve, and is shown on the same Plate.

The daily cumulative rainfall curve shows the amount of rain that fell on the drainage area. The cumulative discharge curve shows the amount of water that was discharged from the river. Therefore, the difference in amount of these two curves represents the amount of rainfall that fell on the drainage area but was not discharged by the river; hence it was retained on the drainage area either in the soil or by vegetation, or else it was lost by evaporation. These differences were figured and plotted on the same co-ordinates on Plate VIII, as shown by the dotted curve. This gives a cumulative retention

curve showing directly the difference in amounts between rainfall and runoff for the given period of time.

Storage

Due to the topography of the Flambeau River above the dam site, it is found possible to construct a dam so as to impound a considerable amount of water. The quantity of water which can be impounded depends of course upon the height of the dam and the depth to which the water is drawn during periods when the stored water is needed to augment the natural river flow. As the water is lowered, the head will be reduced, which fact has been considered in all power calculations.

From a study of the map of the pondage area which is shown in Plate IX, it is seen that the dam may be readily built up to elevation 1275, which, as the elevation of the river is 1195, gives a maximum head of 80 feet. It was decided to make the minimum head 60 feet, thus operating between the limits of elevation 1275 and elevation 1255, or 60 to 80 foot heads. This gives an amount of storage water that may be drawn off to augment low flow equal to the volume of water between elevation 1255 and 1275. This volume of pondage was found by planimetering the pondage area and multiplying by the depth. The volume so determined was found to be 1,427,250,000 cu. ft.

Having obtained the amount of pondage, it is necessary to find the number of horsepower hours which this volume of water will develop. The average head or fall of this pondage water will be 75 feet. Therefore, the horsepower hours due

to pondage $= \frac{1,427,250,000 \text{ cu.ft.} \times 75 \text{ ft.} \times 62.5}{33,000 \times 60}$

$= 3,380,000$ H.P. Hours.

Power Hydrograph

The hydrograph for the minimum year of 1904 has also been prepared to show the actual horsepower corresponding to the actual stream flow. The basis of this calculation is the power delivered by turbines of 80% efficiency under a head of 80 feet. The power scale is placed at the right of this hydrograph and measures the available daily power in horsepower hours. (See Plate II).

The method of determining the amount of horse power that may be developed is as follows: the horizontal dotted lines on the power hydrograph represent various horse powers. Wherever the hydrograph lies above the given horse power line, there is enough water to develop this power, but where the hydrograph lies below the line, there is not enough water flowing in the river to develop that amount of horse power. This deficiency must be made up by the storage which was found to be 3,380,000 horse power hours. Now by measuring the area lying between the given horse power line and that part of the hydrograph lying below the horse power line, the number of horse power hours necessary to make up the deficiency is found. Thus, for any particular power, the amount of storage necessary to develop this power can be found. This was done for various powers as follows:

To develop 8,000 H. P.

Required H. P. hours of pondage . . . 3,510,000

H. P. Hrs. of pondage available . . . 3,380,000

To develop 7,000 H.P.

Required H. P. hours of pondage . . . 2,880,000

H. P. hours of pondage available . . 3,380,000

To develop 6,000 H. P.

Required H. P. hours of pondage . . . 2,440,000

H. P. hours of pondage available . . 3,380,000

From the above calculations a development of 7,000 H. P. was decided on. This amount of power can be developed continuously without an auxiliary steam plant. By constructing the power hydrograph for 1904, these figures are based on the lowest year for which data is available.

## DESIGN

### Study of Flood Conditions

One of the most important factors in dam design is that the spillway or tainter gate section shall be of sufficient capacity. This means that this overflow section must be designed for the maximum flood. In order to make a determination of this maximum flood, a study of flood water conditions in the past on the Flambeau River as well as adjacent rivers is necessary. This study extended over observations taken for a period of seven years, from 1903 to 1910 inclusive. The flood conditions of six rivers were observed, namely, the

Flambeau, Chippewa, Black, Wolf, Wisconsin, and Menominee. Knowing the maximum discharge for a given year on a certain river, as obtained from the government data, and knowing the drainage area of the river above the point at which this discharge obtained, it was possible to calculate the maximum flood flow in second feet per square mile of drainage area. This was done for each river for the given years. (For data see Appendix C.) The maximum flood flow occurring on any river for any year was that on the Black in 1905, when a flow of 17.5 sec. ft. per square mile was obtained. The maximum flood flow noted on the Flambeau was in 1906, which gave a flow of 5.2 sec. ft. per square mile. After a study of this data it was decided to design the tainter gate section for a flood flow of 10 sec. ft. per square mile. Although a flow of over 17 sec. ft. was noted on the Black, it is certain that like conditions could never obtain on the Flambeau as the small size and topography of the drainage area, which includes many small lakes and tributaries acting as natural reservoirs, limits the flood flow, and it is hardly possible that a greater flow than 10 sec. ft., which is twice as great as any previously noted, could ever occur.

Design of Tainter Gates:

Assuming a flood flow of ten second feet, the total discharge will be 10 x 2120 (drainage area) = 21,200 sec. ft. A certain part of this flow goes through the turbines that are delivering power, which amount depends on the head. Under

flood conditions the head will be about 65 feet, and the amount of power being developed will be at least 4000 H. P., or with 80% efficiency at turbines, the discharge will correspond to a power of 5000 H. P. Thus the discharge will be

$$\frac{5,000 \times 550}{60 \times 62.5} = 735 \text{ sec. ft.}$$

The amount of water that will have to pass through the tainter gate section will then be 21,200 - 735 or 20465 second feet.

Under flood conditions the velocity of the water passing the tainter gates was figured to be 10 feet per second. Therefore to pass a flood of 20465 second feet, a cross section equivalent to $\frac{20465}{10}$ or about 2050 sq. ft. is necessary. The tainter gates are to be ten feet in depth. Thus the length of the tainter gate section must be $\frac{2050}{10}$ or 205 feet. It was decided to use fifteen 14' x 10' gates, which gives a length of 210 feet.

Layout of Dam

A large topographical map of the dam site was plotted up on which the layout was made. The tainter gate section as designed was laid out in the middle of the stream, with the power house on the east bank and the log and fish way to the left of the tainter gates. (See Plate X). The dam proper will consist of a high head concrete gravity section the top of which will be at elevation 1280. At each end of this section two earthen embankments with concrete core walls join on to the gravity section by means of concrete wing walls.

The cross section (Plate XI) shows the elevation of the different sections and the elevation and slope of the ground and bed rock surfaces.

Design of Dam - High Head Section

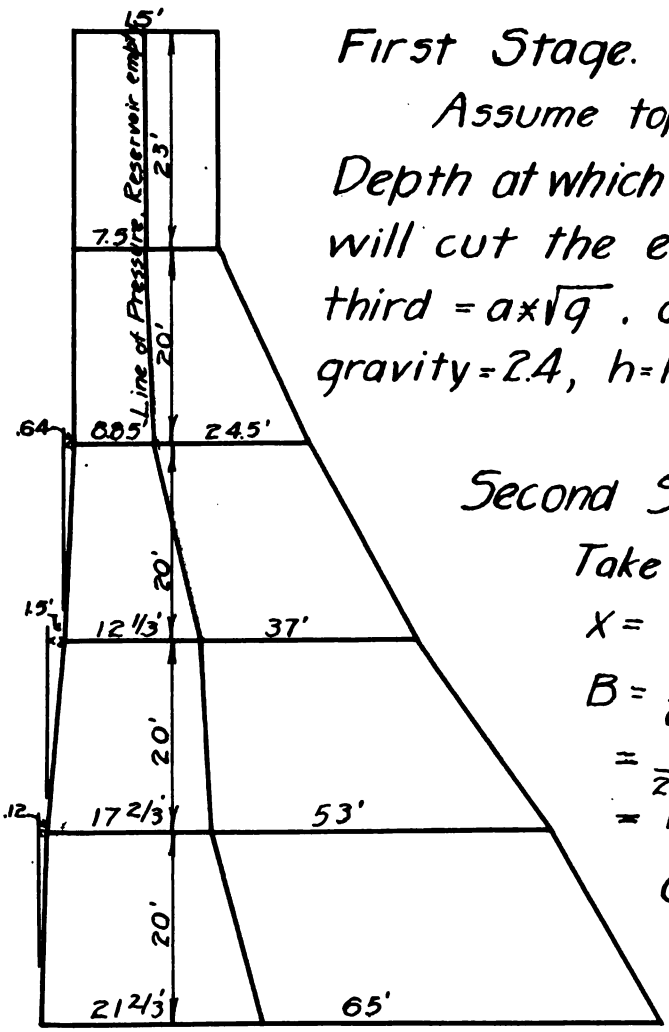
The high head section was designed according to Wegmann's method of determining the theoretical profile. This method consists in determining at successive horizontal sections beginning at the top the necessary size of section to fulfill conditions of stability. By this method, taking sections sufficiently close, the profile may be determined with any desired degree of exactness. Sections 20' deep were taken in this case, and a top width of 15' assumed.

After the theoretical profile is calculated, a practical profile is fitted over it. For this practical profile see Plate XIII. The calculations for this theoretical profile are given on pages 10-a and 10-b.

Design of Weir Section

The overflow section under the tainter gates requires a little special design as a crest of ten feet passes over it and it has a ten foot smaller head. For this overflow weir an Ogee section was determined upon. The object of this form is to guide the water smoothly over the dam, and to deliver it at the bottom tangentially with the stream bed. The convex curve to be given to a dam should be full enough to prevent the water from leaving the surface. Such a curve is a parabola whose equation is $y = \frac{g}{2v^2}-x^2$. (Taken from Turneaure &

# Calculation of Theoretical Profile.




## First Stage.

Assume top width to be 15'.

Depth at which resultant pressure will cut the edge of the middle third = $a\times\sqrt{q}$. $a=15'$, $q$ = specific gravity = 2.4, $h=15\sqrt{2.4}=23.9$. Use 23'

## Second Stage.

Take 20' Sections.

$$X=\sqrt{B+C^2}-C$$

$$B=\frac{d^3}{gh}+\frac{6AM}{h}+l^2$$

$$=\frac{43^2}{2.4\times20}+\frac{6\times23\times15\times7.5}{20}+15^2$$

$$=1670+725+225=2670$$

$$C=1/2\left(\frac{4A}{h}+l\right)$$

$$=1/2\left(\frac{4\times23\times15}{20}+15\right)=42$$

$$X=\sqrt{2670+42^2}-42=24.5$$

$$n=\frac{(24.5^2+15\times24.5+15^2)\frac{20}{6}+23\times15\times7.5}{15\times23+\frac{15\times24.5}{2}\times20}=8.85$$

$n > X/3$ . . O.K.

## Third Stage.

$$x=\sqrt{\frac{d^3}{gh}+\left(\frac{l}{2}+\frac{A}{h}\right)^2}-\left(\frac{l}{2}+\frac{A}{h}\right)$$

$$=\sqrt{\frac{63^2}{24\times20}+\left(\frac{24.5}{2}+\frac{740}{20}\right)^2}-\left(\frac{24.5}{2}+\frac{740}{20}\right)$$

$$=\sqrt{5000+2425}-49.25=37.0'$$

$$y=\frac{2A(x-3m)-hl^2}{6A+h(2l+x)}$$

$$=\frac{2\times740(37-3\times8.85)-20\times24.5^2}{6\times740+20(2\times24.5+37)}=\frac{3900}{6160}=.635$$

## Fourth Stage.

$$x = \sqrt{\frac{83^2}{24 \times 20} + \left(\frac{37}{2} + \frac{1354}{20}\right)^2} - \frac{37}{2} + \frac{1354}{20}$$

$$= \sqrt{11900 + 7400} - 86 = 53'$$

$$y = \frac{2 \times 1354(53 - 3 \times 12.33) - 20 \times 37^2}{6 \times 1354 + 20(2 \times 37 + 53)}$$

$$= \frac{2708 \times 16 - 27{,}400}{8120 + 2540} = \frac{15900}{10{,}660} = 1.5'$$

## Fifth Stage.

$$x = \sqrt{\frac{103^2}{24 \times 20} + \left(\frac{53}{2} + \frac{2254^2}{20}\right)} - \left(\frac{53}{2} + \frac{2254}{20}\right)$$

$$= \sqrt{27{,}600 + 19{,}300} - 139 = 65'$$

$$y = \frac{2 \times 2254(65 - 3 \times 17.66) - 20 \times 53^2}{6 \times 2254 + 20(2 \times 53 + 65)}$$

$$= \frac{4508 \times 12 - 5600}{13{,}524 + 3420} = \frac{2000}{16{,}944} = .12'$$

Russell's Public Water Supply.) This curve was calculated and plotted as shown in Plate XII. Knowing this curve, it was figured that a base of 65 ft. was ample to give stability to the dam under the given conditions. This base is further extended by a concrete apron which is provided to take care of the scouring effect. This increases the length of the base to a total of 100 ft. For the details of this section as well as that of the earth section and cross section of the piers see Plate XIII.

## ESTIMATE

From the cross section of the layout (Plate XI) and the different dam sections (Plate XIII) the amounts of excavation and also the amounts of concrete and earth embankment were estimated. A detailed estimate of these quantities follows:

### Excavation

1. East Core Wall, width 2'

| STATION | DEPTH | AREA | AV. AREA | VOLUME CU.YDS. |
|---|---|---|---|---|
| 0 | 14 | 28 | 28 | 104 |
| 1 | 14 | 28 | 27 | 100 |
| 2 | 13 | 26 | 25.5 | 94.5 |
| 3 | 12.5 | 25 | 25.5 | 94.5 |
| 4 | 13.0 | 26 | 26 | 48 |
| 4+50 | 13 | 26 | | |
| | | T o t a l - - - - | | 441 cu.yds. |

2. East Wing Walls.

20' long x 3' wide at base x $\frac{13+13}{2}$ ( aver.depth )

= 780 cu. ft.

Two walls = $\frac{2 \times 780}{27}$ = 58 cu. yds.

### 3. High Head Section

| STATION | AREA | AVER. AREA | VOLUME |
|---|---|---|---|
| 4 + 50 | 240 | | |
| | | 253 | 445 |
| 5 | 266 | | |
| | | 309 | 1145 |
| 6 | 352 | | |
| | | 397 | 1470 |
| 7 | 442 | | |
| | | 436 | 1610 |
| 8 | 429 | | |
| | | 440 | 1630 |
| 9 | 450 | | |
| | | 410 | 1520 |
| 10 | 371 | | |
| | | 388 | 935 |
| 10+65 | 405 | | |
| 13+60 | 236 | | |
| | | 232 | 515 |
| 14 | 228 | | |
| | | 339 | 1255 |
| 15 | 450 | | |
| | | 455 | 1685 |
| 16 | 460 | | |
| | | 415 | 1540 |
| 17 | 370 | | |
| | | 362 | 1340 |
| 18 | 354 | | |
| | | 357 | 1325 |
| 19 | 360 | | |
| | | 368 | 1365 |
| 20 | 378 | | |
| | | 336 | 1245 |
| 21 | 294 | | |
| | | 294 | 1090 |
| 22 | 294 | | |
| | | 287 | 1025 |
| 23 | 280 | | |
| | | 257 | 950 |
| 24 | 234 | | |
| | | 213 | 586 |
| 24 + 75 | 192 | | |

T o t a l . . . . . 22676 cu.yds.

### 4. West Wing Walls.

$$2/27 \left(20 \times 3 \times \frac{11\ 12}{2}\right) = 51 \text{ cu.yds.}$$

### 5. West Core Wall

| STATION | DEPTH | AREA | AV. AREA | VOLUME |
|---|---|---|---|---|
| 24 + 75 | 12 | 24 | | |
| | | | 23 | 21 |
| 25 | 11 | 22 | | |
| | | | 22 | 82 |
| 26 | 11 | 22 | | |
| | | | 21 | 78 |
| 27 | 10 | 20 | | |
| | | | 22 | 82 |
| 28 | 12 | 24 | | |
| | | | 23 | 85 |
| 29 | 11 | 22 | | |
| | | | 20 | 74 |
| 30 | 9 | 18 | | |
| | | | 17 | 63 |
| 31 | 8 | 16 | | |

T o t a l . . . . . 485 cu. yds.

6. Excavation through Spillway 100' wide.

| STATION | DEPTH | AREA | AV. AREA | VOLUME |
|---|---|---|---|---|
| 10 + 65 | 7 | 700 | | |
| | | | 550 | 712 |
| 11 | 4 | 400 | | |
| | | | 425 | 1570 |
| 12 | 4.5 | 450 | | |
| | | | 475 | 1760 |
| 13 | 5 | 500 | | |
| | | | 450 | 1665 |
| 13 + 60 | 4 | 400 | | |
| | | Total . . . . . | | 5707 cu.yds. |

7. Power House

$$1/27 \times 125' \times 45' \times \frac{13 + 29}{2} = 4380 \text{ cu. yds.}$$

TOTALS.

1. East Core Wall . . . . . 441 cu.yds.
   West Core Wall . . . . . 485
   East Wing Wall . . . . . 58
   West Wing Wall . . . . . 51
   High Head Section. . . . . 22676
   Spillway excavation. . . . . 5707
   Power House. . . . . 4380

   33,798 cu.yds.

25% Rock Excavation . . . . . 8450 cu.yds.
75% Earth Excavation . . . . . 25350 cu.yds.

## AMOUNT OF EARTH EMBANKMENT

| STATION | AREA | AV. AREA | VOLUME |
|---|---|---|---|
| 0 | 00 | | |
| | | 40 | 148 |
| 1 | 80 | | |
| | | 140 | 520 |
| 2 | 200 | | |
| | | 320 | 1185 |
| 3 | 440 | | |
| | | 600 | 2220 |
| 4 | 760 | | |
| | | 880 | 1630 |
| 4 + 50 | 1000 | | |
| | | | |
| 24 + 75 | 1000 | | |
| | | 900 | 835 |
| 25 | 800 | | |
| | | 660 | 2440 |
| 26 | 520 | | |
| | | 460 | 1700 |
| 27 | 400 | | |
| | | 250 | 925 |
| 28 | 100 | | |
| | | 75 | 278 |
| 29 | 50 | | |
| | | 38 | 140 |
| 30 | 25 | | |
| | | 12 | 45 |
| 31 | 0 | | |
| | T o t a l . . . . | | 12066 cu.yds. |

## AMOUNT OF CONCRETE

1. Core Walls - 2' wide

| STATION | DEPTH | AV. DEPTH | VOLUME |
|---|---|---|---|
| 1 + 25 | 12 | | |
| | | 14 | 78 |
| 2 | 16 | | |
| | | 17.5 | 130 |
| 3 | 19 | | |
| | | 20.5 | 152 |
| 4 | 22 | | |
| | | 24 | 89 |
| 4 + 50 | 26 | | |
| | | | |
| 24 + 75 | 25 | | |
| | | 24.5 | 45 |
| 25 | 24 | | |
| | | 22 | 163 |
| 26 | 20 | | |
| | | 18 | 133 |
| 27 | 16 | | |
| | | 14.5 | 107 |
| 28 | 13 | | |
| | | 12 | 44 |
| 28 + 50 | 11 | | |
| | T o t a l . . | | 941 cu. yds. |

## 2. High Head Section.

| STATION | AREA | AVER. AREA | VOLUME |
|---|---|---|---|
| 4 + 50 | 471 | | |
| | | 495 | 917 |
| 5 | 520 | 590 | 2180 |
| 6 | 660 | 740 | 2740 |
| 7 | 820 | 920 | 3410 |
| 8 | 1020 | 1300 | 4800 |
| 9 | 1580 | 1990 | 7360 |
| 10 | 2300 | 2700 | 6500 |
| 10 + 65 | 3100 | | |
| 13 + 60 | 3020 | | |
| | | 2940 | 4350 |
| 14 | 2860 | 2560 | 9500 |
| 15 | 2260 | 1920 | 7100 |
| 16 | 1380 | 1300 | 4810 |
| 17 | 1220 | 1090 | 4040 |
| 18 | 960 | 930 | 3440 |
| 19 | 900 | 840 | 3110 |
| 20 | 780 | 750 | 2780 |
| 21 | 720 | 660 | 2440 |
| 22 | 600 | 590 | 2190 |
| 23 | 580 | 540 | 2000 |
| 24 | 500 | 480 | 1330 |
| 24 + 75 | 460 | | |
| | | T o t a l . . . . | 74997 cu.yds. |

## 3. Wing Walls

$20 \times 2.5 \times 30 = 1500$

$4 @ \frac{1500}{27} = 222$ cu.yds.

## 4. Tainter Gate Section

Note: Bottom of section laid on level excavation. Therefore same length and section over all.

Area of section = 3400 sq. ft.

$$\text{Vol.} = \frac{3400 \times 210}{27} = 26{,}400 \text{ cu.yds.}$$

## 5. Piers.

18 piers, average depth 103', 4' wide.

Vol. of 1 pier = $4 \times 4480 \quad \frac{5 \times 4}{2} \times 103 = 18930$ cu.ft.

Vol. of 18 piers = $\frac{18 \times 18930}{27} = 12{,}600$ cu.yds.

## 6. Operating Platform

Area of Section = $3 \times 1 + 1 \times 1 = 4$ sq. ft.

Volume = $\frac{4 \times 210}{27} = 31$ cu.yds.

## TOTALS

| | | |
|---|---|---|
| High Head Section . . . . . | 74,997 | cu.yds. |
| Core walls , . . . . . | 941 | |
| Wing Walls,. . . . . | 222 | |
| Weir Section . . . . . | 26,400 | |
| Piers . . . . . | 12,600 | |
| Operating Platform. . . . . | 31 | |
| | | 115,191 cu.yds. |

## COST ESTIMATE

FROM a study of amounts, local conditions with regard to current prices, and such cost data as was available, the following cost estimate was made up.

**Concrete**

| | | | | |
|---|---|---|---|---|
| High head section, | 74997 | cu.yds. | @ $6.00 . . . | $ 449,982. |
| Core Walls, | 941 | " | @ 8.00 . . . | 7,528. |
| Wing Walls, | 222 | " | @ 8.00 . . . | 1,776. |
| Weir Section, | 26400 | " | @ 8.00 . . . | 211,200. |
| Piers, | 12600 | " | @ 8.00 . . . | 100,800. |
| Operating Platform, | 31 | " | @ 13.00 . . . | 403. |

**Earth Embankment**

12,066 cu.yds. @ $.40 . . . . . 4,825.

**Excavation**

Earth, 25,350 cu.yds. @ $.35 . . . . . 8,860.

Rock, 8,450 cu.yds. @ $1.50 ,. . . . . 12,700.

Rock

**Timber Trestle** - For log and fishway.

M = L(240 9 H) = 350(240 9x55) = 242,000

242 M At $80.00 per M . . . . . 19,360.

**Power House**

120 x 50 x 45 = 270,000 cu.ft. @ $.16 . . . . 43,200.

Grand Total . . . . . $ 860,634.

## TURBINE AND GENERATOR SELECTION

### Selection of the Number of Units

The design of this plant calls for a development of 7000 H. P. or approximately 5200 kilowatts. It was decided to install four 1200 K. W. generators which would give a total of 4800 K. W. or very near the maximum available power, providing all were operated continuously. However, until a market is built up, not more than three quarters of this amount of power will be sold, or about 3600 K. W. This permits of one generator to be used for a reserve unit.

In all turbines the quantity of discharge, the speed, the power, the efficiency and the head on the wheel are closely related and vary in accordance with certain definite laws modified by the design of the turbine and the conditions under which it is to operate. In any particular case, the conditions are fairly well fixed, and the problem of turbine selection becomes one of finding some standard wheel which will best fit the given conditions. In this case where the turbines are direct connected to the generators, the generators must run at a given constant speed which necessitates the selection of a turbine that will give that speed. For the service for which the generators are to be put, a 60 cycle machine will be used and a 1200 K. W. unit has been decided upon. Knowing these two conditions, the factor which will affect the operating speed of the generator will be the number of pairs of field poles. Following is a table of the speeds of a 1200 K. W. 60 cycle generator for various numbers of poles:

| | |
|---|---|
| For 18 pairs of poles - - - - | Speed 200 R. P. M. |
| 17 | 208 |
| 16 | 225 |
| 15 | 240 |
| 14 | 257 |
| 13 | 276 |
| 12 | 300 |
| 11 | 327 |
| 10 | 360 |
| 9 | 400 |
| 8 | 450 |
| 7 | 514 |
| 6 | 600 |

Knowing these speeds at which operation may take place, it is necessary to find some wheel whose economical speed will correspond at least closely with one of these values, and then farther test that wheel out for its efficiency at the desired power output.

The power required for each unit is 1200 K. W., or 1600 H. P. There will be two runners on each shaft, so that two wheels will be furnishing power to one generator, therefore the required power from each wheel will be 800 H. P. Now knowing the average head at which the wheel will operate, and the required power, the economical speed of the wheel may be found by substituting in the formula, $K_5 = n^2 P/h^{5/2}$ in which n is the speed, P the power, h the head, and $K_5$ a constant which

is known for certain types or series of wheels. By this formula the economical speed of a number of wheels were figured, having given their values of $K_5$.

| Make of Wheel | Economical Speed R.P.M. |
|---|---|
| Sampson | 482 |
| Improved Sampson | 565 |
| Smith-McCormick | 415 |
| Smith | 625 |
| Standard Trump | 480 |
| Allis-Chalmers Type F | 566 |
| Allis-Chalmers #1883 | 445 |
| Wellman-Seaver-Morgan Co. | 538 |
| James Leffel & Co. #1924, | 552 |
| James Leffel & Co., #1899 | 525 |

Comparing this table with the allowable generator speeds, it may be seen that there are only two wheels that closely fit an allowable speed. These are the Smith-McCormick to run at 400 R. P. M., and the Allis-Chalmers #1883 to run at 450 R. P. M. These two wheels were analyzed.

Analysis of the Smith-McCormick wheel

From the formula $P = K_2 D^2 h^{3/2}$, where D is the diameter of the wheel and $K_2$ is a known constant, the diameter of the desired wheel to operate under the given conditions was found to be 25 inches. Then from a test on a Smith-McCormick wheel the efficiency, discharge, and horsepower curves were plotted. (See Plate XIV). These curves are plotted against $\phi$, which is

the constant ratio of the peripheral velocity of the wheel to the spouting velocity of the water, and they show the actual efficiency developed, the power developed, and the amount of discharge for the wheel in question between the operating heads of 60 and 80 feet. Having given these curves, the horse-power efficiency curve may be plotted (See Plate XIV) which shows for the two limiting heads the efficiency of the wheel at whatever amount of power it is developing. This curve furnishes the basis for the actual selection of the wheel.

Analysis of the Allis-Chalmers Co. #1883 wheel

Following the same analysis, the diameter of the proposed wheel was computed to be 26". In the case of this wheel a test was obtained from which the efficiency, horse power, and discharge curves had already been plotted. By means of these curves the efficiency horsepower curve was plotted directly, and placed on the same set of co-ordinates with the efficiency horsepower curve of the Smith-McCormick wheel for the purpose of comparison.

Comparison of the Wheels

In the Smith-McCormick wheel, the 80' head gives a lower efficiency than the 60' head. Also the maximum efficiency of this wheel comes at a power of about 600 H. P., and by the time it has reached 800, the desired horsepower, the efficiency drops to 81%. The other wheel fits the conditions much better as at an 80' head and delivering a power of 800 H. P., the

ordinary conditions of operation, it has an efficiency of 87%. Under both heads and for practically all conditions, the Allis Chalmers wheel has higher efficiencies than the Smith-McCormick.

From the results of this analysis, the installation will consist of eight 26" Allis-Chalmers Type E, (#1883) turbines, two on a shaft, direct-connected to four 1200 K. W., 60cycle 16 pole generators.

## MONTHLY RAINFALL IN INCHES FOR VARIOUS STATIONS

**Legend:**

| | | |
|---|---|---|
| Medford | Station | No. 1 |
| Butternut | " | No. 2 |
| Hayward | " | No. 3 |
| Ashland | " | No. 4 |
| Barron | " | No. 5 |
| Appolonia | " | No. 6 |
| Prentice | " | No. 7 |
| Ladysmith | " | No. 8 |
| Weyerhauser | " | No. 9 |

### YEAR 1889

| STAS. | JAN. | FEB. | MAR. | APR. | MAY. | JUNE | JULY | AUG. | SEPT. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | 3.40 | 2.83 | 2.78 | .05 | 1.70 | 2.18 |
| 2 | | | | | | | | | | .38 | 2.73 | 1.73 |
| Aver: | | | | | | | 3.40 | 2.83 | 2.78 | .21 | 2.21 | 1.95 |

### YEAR 1890

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.19 | 1.56 | 1.76 | 1.70 | 4.38 | 4.50 | 3.43 | 6.17 | 7.87 | 3.68 | .80 | .80 |
| 2 | 1.02 | 5.42 | | 1.58 | 3.73 | 3.77 | 6.46 | 5.76 | 4.75 | 3.12 | .94 | .39 |
| 3 | | | | | | | | 3.45 | | 2.56 | .91 | .28 |
| AVER: | 1.10 | 3.49 | 1.76 | 1.64 | 4.06 | 4.14 | 4.95 | 5.13 | 6.31 | 3.12 | .88 | .49 |

### YEAR 1891

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.13 | 2.33 | 2.23 | 2.72 | .46 | 3.99 | 1.75 | 2.63 | 2.78 | 3.65 | .48 | 5.06 |
| 2 | 1.11 | 1.73 | 2.05 | 1.57 | .70 | 2.64 | | 2.53 | 1.71 | 2.40 | | |
| 3 | .85 | 2.28 | 2.42 | 1.46 | 2.15 | 1.91 | 3.33 | 1.81 | 1.93 | 2.16 | .80 | 3.35 |
| 4 | 1.13 | 2.23 | 2.11 | 2.14 | 1.34 | 4.57 | 1.51 | 3.26 | 2.86 | 2.72 | 1.68 | 2.81 |
| 5 | | | | | | 2.68 | 1.86 | 1.42 | 1.46 | 1.90 | .70 | .52 |
| AVER: | 1.31 | 2.14 | 2.18 | 1.97 | 1.16 | 3.20 | 2.11 | 2.33 | 2.15 | 2.57 | .91 | 2.94 |

### YEAR 1892

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.35 | 1.57 | 1.10 | 2.03 | 6.60 | 9.50 | 4.85 | 2.03 | 1.91 | 2.38 | 1.25 | .50 |
| 2 | .30 | 2.30 | 1.30 | .30 | 2.15 | | | | | | | .56 |
| 3 | .51 | 1.71 | 1.43 | 3.10 | 4.00 | | | | | | | |
| 4 | 1.24 | 1.49 | 1.87 | 2.90 | 4.96 | 2.41 | 3.03 | 4.01 | .45 | 1.32 | 1.54 | .44 |
| 5 | .26 | 1.73 | .98 | 2.29 | 7.03 | 7.44 | 4.61 | 3.94 | 1.77 | 1.80 | 1.04 | .71 |
| AVER: | .73 | 1.76 | 1.33 | 2.12 | 5.19 | 6.45 | 4.16 | 3.33 | 1.38 | 1.83 | 1.28 | .55 |

## YEAR 1893

| STAS | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .76 | 2.25 | 1.65 | 3.45 | 3.46 | 1.98 | 2.80 | 1.57 | 2.14 | 3.00 | .90 | 2.65 |
| 2 | .44 | 1.34 | 1.67 | 2.52 | 3.88 | | 5.14 | 5.01 | 2.37 | 3.77 | .70 | 2.26 |
| 3 | 1.00 | 3.00 | 2.37 | 2.05 | 2.50 | 1.25 | 6.50 | 4.12 | 2.24 | 3.20 | .65 | 1.73 |
| 4 | 1.23 | 4.10 | 2.51 | 2.76 | 2.22 | 2.68 | 3.72 | 1.32 | 1.45 | 3.20 | 1.49 | 1.93 |
| 5 | 1.23 | 2.91 | 1.75 | 4.91 | 3.85 | 1.25 | 3.28 | 3.66 | 2.85 | 3.40 | | 2.05 |
| AVER. | .93 | 2.72 | 1.99 | 3.14 | 3.18 | 1.79 | 4.29 | 3.14 | 2.21 | 3.32 | .94 | 2.12 |

## YEAR 1894

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.10 | 1.30 | 1.95 | 4.07 | 4.66 | 2.59 | .93 | 1.75 | 2.86 | 3.14 | 1.58 | 1.00 |
| 2 | .77 | .27 | 3.23 | | | | | | | | .90 | .84 |
| 3 | 1.30 | .30 | 1.90 | 1.70 | 4.59 | 1.14 | .56 | .72 | 1.66 | 3.78 | 1.29 | .71 |
| 4 | 1.28 | 1.03 | 5.09 | 3.80 | 6.45 | 2.90 | 1.30 | 1.82 | 2.27 | 4.98 | 1.20 | .20 |
| 5 | 1.68 | .45 | 2.44 | 4.66 | 8.94 | 2.01 | 2.40 | 1.30 | 1.85 | 4.73 | 1.40 | 1.24 |
| AVER. | 1.23 | .67 | 2.92 | 3.55 | 6.16 | 2.16 | 1.30 | 1.37 | 2.16 | 1.66 | 1.27 | .80 |

## YEAR 1895

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.47 | .35 | .34 | 1.05 | 6.08 | 4.93 | 3.86 | 3.19 | 3.32 | .52 | 1.84 | 1.28 |
| 2 | 1.37 | .63 | .30 | .38 | 6.15 | 5.38 | 4.31 | | 10.0 | 2.1 | .28 | 2.03 |
| 3 | .92 | .33 | .54 | .83 | 4.52 | 7.74 | 2.75 | 5.19 | 6.5 | .26 | .82 | .95 |
| 4 | 2.30 | .00 | .11 | .15 | | | | | | | | 1.40 |
| 5 | .83 | .60 | .48 | 1.68 | 3.03 | 4.87 | 4.93 | 1.78 | 3.90 | .26 | .80 | 1.66 |
| 6 | 1.35 | .10 | .53 | 1.53 | 3.90 | 4.36 | 4.95 | 1.52 | 4.99 | .36 | .73 | 1.04 |
| AVER. | 1.37 | .34 | .38 | .94 | 4.74 | 5.46 | 4.16 | 2.94 | 5.78 | .38 | .89 | 1.39 |

## YEAR 1896

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.50 | .78 | .95 | 2.61 | 5.22 | 4.10 | 6.15 | 3.18 | 2.33 | 2.45 | 3.06 | .59 |
| 2 | 1.54 | .49 | 1.70 | 3.18 | 4.04 | | 9.45 | | | | | |
| 3 | 2.40 | .51 | 1.95 | 7.06 | 5.10 | 3.21 | 1.40 | 1.57 | 2.03 | 2.70 | 1.51 | 2.44 |
| 4 | .70 | .65 | .75 | 4.30 | 3.62 | 1.75 | 1.71 | 1.00 | 1.27 | 3.64 | 3.22 | 1.20 |
| 6 | 1.00 | .20 | 2.04 | 5.38 | 5.70 | 4.35 | 2.96 | 3.94 | 2.18 | 3.82 | 6.74 | .90 |
| AVER. | 1.63 | .53 | 1.48 | 4.51 | 4.74 | 3.35 | 4.34 | 2.42 | 1.95 | 2.85 | 3.93 | 1.28 |

## YEAR 1897

| STAS | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.02 | .66 | 2.15 | 1.34 | 1.45 | 8.12 | 5.27 | 2.59 | 1.90 | 2.45 | .04 | .40 |
| 2 | 1.35 | .88 | 1.56 | | | 6.54 | 15.1 | 1.31 | 2.38 | 2.01 | 1.25 | |
| 3 | 1.94 | 2.28 | 3.39 | .31 | 2.34 | 5.81 | 5.00 | 4.30 | 3.00 | 3.06 | 1.34 | .41 |
| 4 | 2.00 | .80 | 1.60 | 1.05 | 2.07 | 4.41 | 8.21 | 3.39 | 2.86 | 1.67 | 1.06 | 1.20 |
| 5 | 2.03 | 1.75 | 2.60 | 1.86 | 2.07 | 6.23 | 5.54 | 1.25 | 2.93 | 1.85 | .29 | .30 |
| 6 | 1.60 | 1.40 | 3.35 | | | | | | | | | |
| AVER | 1.64 | 1.29 | 2.46 | 1.14 | 2.01 | 6.22 | 7.83 | 2.57 | 2.61 | 2.21 | .79 | .58 |

## YEAR 1898

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .02 | 1.70 | 2.20 | 1.65 | 1.18 | 6.85 | 2.25 | 2.30 | 1.95 | 5.50 | 2.45 | 0.0 |
| 2 | .77 | 1.93 | 1.46 | .83 | 1.27 | | | | | | .25 | |
| 3 | .47 | .98 | 2.65 | .56 | 5.07 | 7.18 | 1.40 | 2.60 | 1.23 | 5.19 | 1.60 | .06 |
| 4 | .80 | 1.80 | .30 | .40 | 2.50 | 1.90 | .55 | 2.20 | 1.60 | 3.40 | 1.40 | 1.75 |
| 5 | .25 | 1.83 | 1.80 | 1.02 | 4.40 | 2.27 | 1.90 | 2.51 | .98 | 4.64 | 1.00 | 0.00 |
| 7 | | | | | 4.30 | 4.97 | 2.20 | 1.66 | 1.79 | 4.27 | 2.43 | .11 |
| AVER | .46 | 1.65 | 1.68 | .89 | 3.12 | 4.63 | 1.66 | 2.25 | 1.51 | 4.60 | 1.54 | .64 |

## YEAR 1899

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .80 | .80 | 1.75 | 1.58 | 6.40 | 5.90 | .75 | 3.80 | 2.80 | 4.50 | .40 | 2.50 |
| 2 | .77 | 1.93 | 1.46 | .83 | 1.27 | | | | | | | .25 |
| 3 | 1.15 | .89 | 2.44 | 1.48 | 4.84 | 4.60 | 1.78 | 4.46 | 2.61 | 6.53 | 1.50 | 1.25 |
| 4 | 1.55 | 1.20 | 1.40 | 2.20 | 2.70 | 4.37 | 3.18 | 4.42 | 3.10 | 3.40 | .30 | 2.30 |
| 5 | .45 | 1.16 | 3.30 | 1.73 | 3.15 | 6.70 | 2.00 | 5.87 | .65 | 4.26 | .95 | 2.02 |
| 7 | .81 | 1.01 | 1.73 | 2.57 | 7.17 | 7.75 | 3.07 | 7.40 | 3.47 | 5.56 | 1.13 | 1.50 |
| AVER | .92 | 1.17 | 2.01 | 1.73 | 4.25 | 5.92 | 2.15 | 5.19 | 2.53 | 4.85 | .85 | 1.46 |

## YEAR 1900

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .85 | 1.10 | .90 | 2.95 | 2.50 | 1.35 | 8.78 | 6.40 | 7.95 | 10.8 | .65 | .75 |
| 2 | .40 | 1.30 | 1.05 | .96 | .91 | 1.16 | 6.55 | 8.86 | 8.07 | 6.02 | 1.77 | 1.17 |
| 3 | 1.53 | 1.50 | 1.66 | 2.45 | .32 | 2.1 | 8.95 | 8.36 | 7.93 | 5.57 | .71 | .92 |
| 4 | 1.80 | 1.00 | .48 | 2.50 | .76 | 1.37 | 5.71 | 4.80 | 4.40 | 2.91 | 1.22 | .84 |
| 5 | 1.16 | | 1.19 | 1.11 | 1.71 | 2.20 | 7.70 | 7.64 | | 5.40 | 1.80 | 1.05 |
| 7 | | | .79 | 3.46 | 1.55 | 3.03 | 13.4 | 7.28 | | | | |
| AVER | 1.15 | 1.28 | .97 | 2.24 | 1.29 | 1.87 | 8.51 | 7.22 | 7.09 | 6.13 | 1.07 | .95 |

## YEAR 1901

| STAS | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | .35 | .35 | 1.75 | .45 | 3.00 | 6.65 | 4.75 | 1.80 | 5.95 | 2.80 | .70 | .50 |
| 2 | .72 | .50 | 2.30 | 1.45 | 1.42 | 5.03 | 5.41 | 5.29 | 3.37 | 1.90 | .60 | .72 |
| 3 | .94 | .48 | 2.15 | 1.85 | 1.07 | 5.38 | 4.00 | 4.40 | 5.47 | 1.33 | .57 | .53 |
| 4 | .37 | .39 | 2.81 | 1.36 | 2.00 | 8.68 | 6.44 | 2.33 | 3.37 | 2.00 | 1.42 | .64 |
| 5 | .49 | .50 | 3.50 | 2.22 | 1.82 | 5.23 | 5.10 | 1.70 | 6.55 | 1.28 | 1.50 | .40 |
| 7 | | | | .90 | 1.31 | 5.50 | 6.14 | 2.80 | 3.71 | 2.28 | .22 | 1.20 |
| 8 | | | | 1.28 | .48 | 5.10 | 1.21 | 1.07 | 4.40 | 1.10 | | 1.20 |
| AVER. | .57 | .44 | 2.50 | 1.36 | 1.60 | 5.94 | 4.78 | 2.77 | 4.69 | 1.81 | .83 | .74 |

## YEAR 1902

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.00 | 1.60 | 1.70 | 3.90 | 5.30 | 2.80 | 7.20 | 5.20 | 4.15 | 3.20 | 5.30 | .70 |
| 2 | .91 | 1.65 | 2.09 | 2.78 | 1.44 | 3.37 | 3.06 | 1.74 | 3.93 | 3.06 | 2.98 | 1.51 |
| 3 | 1.01 | .22 | .40 | 2.18 | 1.28 | 5.13 | 5.36 | 1.96 | 3.96 | 2.40 | 2.42 | 2.33 |
| 4 | .81 | 1.39 | .45 | 2.23 | 1.66 | 2.79 | 4.82 | 1.99 | 4.10 | 1.55 | 2.69 | 1.76 |
| 5 | 1.50 | .26 | .86 | 2.06 | 3.63 | 4.39 | 3.65 | 1.09 | 2.39 | .68 | 4.30 | 1.37 |
| 7 | 1.50 | 2.20 | .73 | 2.46 | 2.45 | 6.11 | 4.74 | 2.85 | 4.41 | 3.01 | 4.77 | 2.80 |
| 8 | 1.95 | .83 | 1.55 | 2.17 | 1.96 | 3.20 | 6.37 | 3.03 | 2.17 | 2.61 | 4.17 | 2.36 |
| AVER. | 1.17 | 1.16 | 1.11 | 2.54 | 2.53 | 3.95 | 5.03 | 2.55 | 3.59 | 2.36 | 3.80 | 1.83 |

## YEAR 1903

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .20 | .20 | 2.35 | 3.95 | 8.25 | .90 | 7.40 | 7.30 | 9.50 | 4.70 | .90 | .50 |
| 2 | .75 | 1.64 | 3.27 | 3.61 | 8.88 | 1.58 | 9.88 | 4.56 | 6.98 | 3.00 | 1.26 | 1.27 |
| 3 | .38 | 1.22 | .92 | 1.49 | 6.18 | 1.78 | 5.88 | 5.06 | 6.35 | 4.95 | 1.48 | 1.05 |
| 4 | .41 | 1.91 | 1.98 | 2.03 | 6.77 | .93 | 6.55 | 5.39 | 5.22 | 3.29 | .80 | 1.11 |
| 5 | .59 | .40 | 2.52 | 2.44 | 5.86 | 3.04 | 6.55 | 4.75 | 5.95 | 3.20 | .50 | .54 |
| 7 | .45 | .60 | | | | | .80 | 4.47 | 7.12 | 1.61 | .86 | 1.83 |
| 8 | .38 | .32 | | | | | | | | .52 | | |
| AVER. | .45 | .90 | 2.21 | 2.70 | 7.19 | 1.65 | 6.18 | 5.25 | 6.85 | 3.04 | .97 | 1.05 |

## YEAR 1904

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .42 | 1.10 | 1.51 | 1.69 | 4.60 | 7.15 | 2.21 | 4.43 | 4.25 | 4.76 | .03 | 1.83 |
| 2 | .67 | .50 | 2.05 | 1.29 | 2.30 | 3.50 | 2.88 | 6.56 | 3.18 | 4.59 | .10 | 2.48 |
| 3 | .36 | .81 | 1.13 | 2.67 | 2.60 | 4.72 | 3.45 | 4.00 | 5.60 | 5.73 | .02 | 1.14 |
| 4 | .22 | 1.08 | 1.64 | .97 | 1.09 | 3.47 | 3.43 | 2.94 | 4.09 | 5.89 | .08 | 1.68 |
| 5 | 1.25 | 1.40 | 1.14 | 2.20 | 6.55 | 8.45 | 6.15 | 5.51 | 6.76 | 5.61 | .00 | .90 |
| 7 | .20 | .90 | 1.30 | 3.05 | 5.95 | 5.90 | 2.85 | 3.90 | 5.75 | 8.00 | .40 | 2.90 |
| AVER. | .52 | .96 | 1.46 | 1.98 | 3.85 | 5.54 | 3.49 | 4.56 | 4.97 | 5.76 | .21 | 1.82 |

## YEAR 1905

| STAS | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .50 | .20 | 1.75 | 1.20 | 5.35 | 16.2 | 6.50 | 5.60 | 3.92 | 1.35 | .65 | .50 |
| 2 | 1.63 | .44 | .98 | .33 | 4.47 | 10.4 | 4.88 | 6.34 | 4.44 | 3.45 | 2.66 | 2.05 |
| 3 | .57 | .37 | 1.10 | 2.14 | 2.68 | 6.66 | 4.91 | 3.54 | 3.93 | 3.07 | 2.80 | .30 |
| 4 | 1.34 | .45 | .77 | 1.98 | 3.13 | 8.10 | 2.47 | 3.48 | 6.58 | 3.42 | 1.80 | .11 |
| 5 | 1.50 | .50 | .47 | 1.00 | 4.50 | 13.7 | 3.50 | 8.50 | 3.70 | 2.40 | 2.70 | .00 |
| 7 | 1.00 | .52 | .28 | .85 | 4.17 | 9.2 | 3.94 | 6.59 | 4.48 | 2.39 | 1.57 | 1.42 |
| 8 | | | | | 4.56 | | | | | | | |
| AVER | 1.09 | .50 | .86 | 1.25 | 4.12 | 10.7 | 4.37 | 5.67 | 4.51 | 2.70 | 2.03 | 1.00 |

## YEAR 1906

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.80 | .20 | .50 | 1.67 | 5.40 | 4.71 | 3.90 | 3.55 | 2.85 | 3.56 | 1.90 | 1.20 |
| 2 | 3.38 | .42 | 1.92 | 2.26 | 4.11 | 4.08 | .79 | 3.41 | 3.85 | 4.39 | 3.37 | 1.05 |
| 3 | 2.00 | .27 | 2.19 | 1.15 | 4.33 | 5.42 | 1.53 | 4.73 | 3.45 | 3.51 | 2.57 | 1.35 |
| 4 | 1.37 | .37 | .90 | 2.12 | 3.59 | 4.43 | 2.38 | 5.30 | 5.04 | 3.03 | 2.90 | 1.71 |
| 5 | 3.20 | .40 | 1.00 | 2.58 | 7.45 | 3.84 | 3.40 | 2.90 | 2.98 | 1.20 | .43 | 1.00 |
| 7 | 4.35 | .30 | 1.10 | 1.41 | 3.51 | 4.45 | 3.41 | 4.68 | 3.50 | 3.74 | 1.76 | 1.53 |
| 9 | | | | | | | | | | 1.14 | 1.88 | |
| AVER | 2.68 | .33 | 1.27 | 1.86 | 4.73 | 4.49 | 2.40 | 4.05 | 3.46 | 3.43 | 2.47 | 1.38 |

## YEAR 1907

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .70 | .20 | .60 | .50 | 2.60 | 3.10 | 1.50 | 3.45 | 5.10 | .90 | .80 | .30 |
| 2 | 1.80 | .70 | 1.52 | 1.06 | 2.14 | 1.89 | | | 8.91 | 1.16 | .68 | .48 |
| 3 | 1.33 | .75 | 1.38 | .66 | 2.14 | 1.80 | 2.52 | 2.28 | 8.50 | .47 | .75 | .47 |
| 4 | 1.12 | .73 | 1.55 | 1.94 | 3.57 | 1.54 | 4.10 | 3.47 | 2.99 | .52 | .49 | .30 |
| 5 | 1.30 | 1.05 | 1.08 | .70 | 1.83 | 3.39 | 2.75 | 2.50 | 3.75 | | | |
| 7 | 1.46 | .27 | 1.89 | 1.65 | 3.08 | 1.96 | 2.08 | 2.05 | 4.82 | 1.17 | 1.09 | .33 |
| 9 | 1.05 | 1.64 | 2.31 | .79 | 2.30 | 2.27 | 4.10 | 2.24 | 5.72 | 1.10 | .90 | .65 |
| AVER | 1.25 | .76 | 1.49 | 1.05 | 2.52 | 2.28 | 2.84 | 2.81 | 5.68 | .52 | .74 | .42 |

## YEAR 1908

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .70 | 1.85 | 1.10 | 2.80 | 5.08 | 4.19 | 4.30 | 2.63 | 3.60 | 3.07 | 2.14 | 1.45 |
| 3 | .67 | .82 | 2.22 | 2.64 | 3.59 | 5.85 | 4.50 | 1.50 | 2.10 | 2.88 | 1.85 | .89 |
| 4 | 1.39 | 1.42 | 1.78 | 2.67 | 6.54 | 2.48 | 4.91 | 1.19 | 1.86 | 2.42 | 1.35 | .59 |
| 5 | .50 | 1.00 | 1.75 | 4.05 | 3.85 | 5.64 | 2.56 | 1.61 | 1.46 | 3.08 | .95 | .87 |
| 7 | .72 | .86 | 2.02 | 2.79 | 4.23 | 5.00 | 3.51 | 2.47 | 2.40 | 1.39 | .88 | .70 |
| 9 | .73 | 1.26 | 1.52 | 3.27 | 6.12 | 4.61 | | 1.35 | 1.94 | 2.85 | 1.04 | 1.15 |
| AVER | .78 | 1.20 | 1.73 | 3.04 | 4.90 | 4.63 | 3.30 | 1.79 | 2.23 | 2.61 | 1.37 | .94 |

## YEAR 1909

| STAS | JAN. | FEB. | MAR. | APR. | MAY | JUNE | JULY | AUG. | SEPT | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .05 | 1.50 | .90 | 2.55 | 1.90 | 3.72 | 3.37 | 2.15 | 3.54 | 2.05 | 5.10 | 1.15 |
| 2 | .43 | | | | | 3.70 | | | 3.09 | | | .62 |
| 3 | .40 | 1.52 | .59 | 3.02 | 2.92 | 2.75 | 3.55 | 3.83 | 2.25 | 3.87 | 4.42 | .58 |
| 4 | .56 | 2.10 | 1.00 | 2.55 | 4.38 | 3.04 | 8.70 | 4.14 | 2.93 | 1.83 | 2.47 | .94 |
| 5 | .35 | 1.35 | .80 | 3.61 | 2.60 | 2.56 | 2.96 | 4.08 | 4.27 | 2.54 | 4.18 | 1.24 |
| 7 | .85 | 1.43 | 1.37 | 3.20 | 3.00 | .86 | 3.60 | 1.90 | 2.51 | 2.45 | 4.52 | .94 |
| 9 | 1.01 | 1.62 | 1.67 | 3.78 | 4.78 | 3.08 | 4.23 | 2.80 | 2.23 | 1.14 | 4.06 | 1.87 |
| AVER | .52 | 1.59 | 1.05 | 3.12 | 3.26 | 2.67 | 4.30 | 3.15 | 2.95 | 2.42 | 4.17 | 1.06 |

## YEAR 1910

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.05 | .20 | .10 | 4.45 | 3.85 | .92 | 2.51 | 5.18 | 2.00 | 2.10 | .60 | .80 |
| 3 | .75 | .90 | .35 | 1.10 | 3.20 | 1.04 | 3.12 | 2.49 | 2.08 | .80 | .50 | 1.00 |
| 4 | .96 | 1.01 | 0.00 | 1.78 | 2.76 | .51 | 3.95 | 1.78 | 3.39 | 1.09 | 0.00 | .82 |
| 5 | 1.19 | .55 | 0.00 | .90 | 2.17 | .74 | 2.21 | 1.80 | 2.07 | 1.54 | 1.40 | .75 |
| 7 | .96 | .77 | .42 | 1.87 | 2.77 | .51 | 3.29 | 3.03 | 2.21 | 1.32 | 1.54 | . |
| 9 | .97 | .78 | .18 | 1.14 | 2.81 | 1.91 | 3.83 | 2.44 | 2.69 | 1.26 | 1.03 | .95 |
| AVER | .98 | .72 | .17 | 1.87 | 2.93 | .94 | 3.15 | 2.80 | 2.51 | 1.33 | .85 | .86 |

## YEAR 1911

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .95 | 1.10 | 1.20 | .75 | 5.60 | 3.25 | 6.48 | 2.84 | 7.32 | 8.80 | 2.60 | 2.85 |
| 3 | .96 | 1.10 | 1.55 | .73 | 2.93 | 2.49 | 6.09 | 3.01 | 5.43 | 3.70 | 1.60 | 1.55 |
| 4 | 1.00 | 1.93 | 1.07 | .54 | 4.79 | 1.77 | 6.07 | 2.45 | 3.79 | 2.34 | 1.66 | 1.48 |
| 5 | .86 | .75 | .88 | 1.27 | 3.68 | 4.37 | 3.90 | 2.79 | 6.75 | 7.26 | 1.39 | 2.13 |
| 7 | | .75 | 1.57 | 2.02 | 4.53 | 2.07 | 4.69 | 1.71 | 4.47 | 6.87 | 2.27 | 2.34 |
| 9 | .59 | .81 | 1.43 | 1.12 | 3.85 | 2.64 | 4.58 | 2.13 | 7.04 | 7.08 | 2.22 | 2.30 |
| AVER | .87 | 1.07 | 1.28 | 1.07 | 4.23 | 2.76 | 5.30 | 2.49 | 5.80 | 6.01 | 1.96 | 2.11 |

## cYEAR 1912

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .30 | .10 | .40 | 3.88 | 6.62 | .12 | 7.45 | 7.69 | 4.75 | 1.80 | .55 | 2.55 |
| 3 | .65 | .45 | .45 | 2.18 | 4.81 | 2.28 | 2.53 | 6.10 | 2.35 | | .22 | 1.44 |
| 4 | .36 | .10 | .17 | 2.64 | 5.34 | 2.27 | 2.13 | 4.76 | 1.00 | 1.14 | .71 | 1.54 |
| 5 | .40 | .25 | .35 | 2.90 | 6.98 | 1.28 | 5.13 | 8.57 | 3.39 | 2.59 | .10 | 1.83 |
| 7 | .37 | .03 | .40 | 3.37 | 8.59 | 1.44 | 7.02 | 7.20 | 3.91 | 2.16 | .44 | 1.44 |
| 9 | .74 | .25 | .62 | 2.67 | 7.01 | 1.27 | 4.50 | 8.27 | 3.56 | 2.21 | .22 | 1.42 |
| AVER | .47 | .20 | .40 | 2.96 | 6.56 | 1.44 | 5.29 | 7.10 | 3.33 | 1.98 | .37 | 1.70 |

## APPENDIX "B"

### DAILY CUMULATIVE RAINFALL FOR THE YEAR 1904

| DATE | DAILY PREC'N. | CUMULATIVE PREC'N. | DATE | DAILY PREC'N. | CUMULATIVE PREC'N. |
|---|---|---|---|---|---|
| JAN. 1, | 0.0" | 0.0" | FEB. 1, | .05" | .50" |
| 2, | .00 | .00 | 2, | .06 | .56 |
| 3, | .00 | .00 | 3, | .00 | .56 |
| 4, | .00 | .00 | 4, | .00 | .56 |
| 5, | .01 | .01 | 5, | .00 | .56 |
| 6, | .00 | .01 | 6, | .01 | .57 |
| 7, | .02 | .03 | 7, | .03 | .60 |
| 8, | .00 | .03 | 8, | .00 | .60 |
| 9, | .00 | .03 | 9, | .00 | .60 |
| 10, | .00 | .03 | 10, | .00 | .60 |
| 11, | .02 | .05 | 11, | .00 | .60 |
| 12, | .04 | .09 | 12, | .06 | .66 |
| 13, | .00 | .09 | 13, | .21 | .87 |
| 14, | .00 | .09 | 14, | .00 | .87 |
| 15, | .00 | .09 | 15, | .00 | .87 |
| 16, | .00 | .09 | 16, | .00 | .87 |
| 17, | .00 | .09 | 17, | .06 | .93 |
| 18, | .01 | .10 | 18, | .07 | 1.00 |
| 19, | .00 | .10 | 19, | .00 | 1.00 |
| 20, | .00 | .10 | 20, | .00 | 1.00 |
| 21, | .31 | .41 | 21, | .03 | 1.03 |
| 22, | .03 | .44 | 22, | .02 | 1.05 |
| 23, | .00 | .44 | 23, | .15 | 1.20 |
| 24, | .00 | .44 | 24, | .02 | 1.22 |
| 25, | .00 | .44 | 25, | .00 | 1.22 |
| 26, | .00 | .44 | 26, | .05 | 1.27 |
| 27, | .00 | .44 | 27, | .01 | 1.28 |
| 28, | .00 | .44 | 28, | .04 | 1.32 |
| 29, | .00 | .44 | 29, | .07 | 1.39 |
| 30, | .00 | .44 | | | |
| 31, | .01 | .45 | | | |

DAILY CUMULATIVE RAINFALL FOR THE YEAR 1904 (Cont.)

| DATE | DAILY PREC'N. | CUMULATIVE PREC'N. | DATE | DAILY PREC'N. | CUMULATIVE PREC'N. |
|---|---|---|---|---|---|
| MAR. 1, | .00" | 1.39" | APRIL 1, | .04" | .2.73" |
| 2, | .34 | 1.73 | 2, | .03 | 2.76 |
| 3, | .03 | 1.76 | 3, | .00 | 2.76 |
| 4, | .00 | 1.76 | 4, | .00 | 2.76 |
| 5, | .00 | 1.76 | 5, | .12 | 2.88 |
| 6, | .00 | 1.76 | 6, | .00 | 2.88 |
| 7, | .00 | 1.76 | 7, | .00 | 2.88 |
| 8, | .00 | 1.76 | 8, | .16 | 3.04 |
| 9, | .02 | 1.78 | 9, | .14 | 3.18 |
| 10, | .08 | 1.86 | 10, | .00 | 3.18 |
| 11, | .01 | 1.87 | 11, | .18 | 3.36 |
| 12, | .00 | 1.87 | 12, | .00 | 3.36 |
| 13, | .01 | 1.88 | 13, | .01 | 3.37 |
| 14, | .22 | 2.10 | 14, | .19 | 3.56 |
| 15, | .00 | 2.10 | 15, | .49 | 4.05 |
| 16, | .00 | 2.10 | 16, | .11 | 4.16 |
| 17, | .00 | 2.10 | 17, | .00 | 4.16 |
| 18, | .00 | 2.10 | 18, | .00 | 4.16 |
| 19, | .18 | 2.28 | 19, | .00 | 4.16 |
| 20, | .00 | 2.28 | 20, | .00 | 4.16 |
| 21, | .11 | 2.39 | 21, | .00 | 4.16 |
| 22, | .00 | 2.39 | 22, | .12 | 4.28 |
| 23, | .00 | 2.39 | 23, | .00 | 4.28 |
| 24, | .18 | 2.57 | 24, | .00 | 4.28 |
| 25, | .02 | 2.59 | 25, | .00 | 4.28 |
| 26, | .00 | 2.59 | 26, | .00 | 4.28 |
| 27, | .00 | 2.59 | 27, | .00 | 4.28 |
| 28, | .00 | 2.59 | 28, | .00 | 4.28 |
| 29, | .01 | 2.60 | 29, | .00 | 4.28 |
| 30, | .00 | 2.60 | 30, | .00 | 4.28 |
| 31, | .09 | 2.69 | | | |

DAILY CUMULATIVE RAINFALL FOR THE YEAR 1904 (Cont.)

| DATE | DAILY PREC'N. | CUMULATIVE PREC'N. | DATE | DAILY PREC'N. | CUMULATIVE PREC'N. |
|---|---|---|---|---|---|
| MAY 1, | .00" | 4.28" | JUNE 1, | .00" | 7.13" |
| 2, | .00 | 4.28 | 2, | .20 | 7.33 |
| 3, | .00 | 4.28 | 3, | .63 | 7.96 |
| 4, | .00 | 4.28 | 4, | 1.50 | 9.46 |
| 5, | .06 | 4.34 | 5, | .30 | 9.76 |
| 6, | .02 | 4.36 | 6, | .08 | 9.84 |
| 7, | .19 | 4.55 | 7, | .02 | 9.86 |
| 8, | .31 | 4.86 | 8, | .00 | 9.86 |
| 9, | .00 | 4.86 | 9, | .00 | 9.86 |
| 10, | .00 | 4.86 | 10, | .00 | 9.86 |
| 11, | .02 | 4.88 | 11, | .00 | 9.86 |
| 12, | .01 | 4.89 | 12, | .06 | 9.92 |
| 13, | .26 | 5.15 | 13, | .00 | 9.92 |
| 14, | .00 | 5.15 | 14, | .03 | 9.95 |
| 15, | .00 | 5.15 | 15, | .00 | 9.95 |
| 16, | .00 | 5.15 | 16, | .00 | 9.95 |
| 17, | .00 | 5.15 | 17, | .02 | 9.97 |
| 18, | .03 | 5.18 | 18, | .04 | 10.01 |
| 19, | .00 | 5.18 | 19, | .04 | 10.05 |
| 20, | .27 | 5.45 | 20, | .02 | 10.07 |
| 21, | .08 | 5.53 | 21, | .01 | 10.08 |
| 22, | .14 | 5.67 | 22, | .14 | 10.22 |
| 23, | .23 | 5.90 | 23, | .90 | 11.12 |
| 24, | .72 | 6.62 | 24, | .00 | 11.12 |
| 25, | .33 | 6.95 | 25, | .40 | 11.52 |
| 26, | .17 | 7.12 | 26, | .20 | 11.72 |
| 27, | .00 | 7.12 | 27, | .00 | 11.72 |
| 28, | .00 | 7.12 | 28, | .26 | 11.98 |
| 29, | .01 | 7.13 | 29, | .34 | 12.32 |
| 30, | .00 | 7.13 | 30, | .33 | 12.65 |
| 31, | .00 | 7.13 | | | |

DAILY CUMULATIVE RAINFALL FOR THE YEAR 1904 (Cont.)

| DATE | DAILY PREC'N. | CUMULATIVE PREC'N. | DATE | DAILY PREC'N. | CUMULATIVE PREC'N. |
|---|---|---|---|---|---|
| JULY 1, | .00 | 12.65 | AUGUST 1, | .01 | 16.02 |
| 2, | .00 | 12.65 | 2, | .00 | 16.02 |
| 3, | .78 | 13.43 | 3, | .02 | 16.04 |
| 4, | .27 | 13.70 | 4, | .07 | 16.11 |
| 5, | .00 | 13.70 | 5, | .00 | 16.11 |
| 6, | .00 | 13.70 | 6, | .24 | 16.35 |
| 7, | .00 | 13.70 | 7, | .31 | 16.66 |
| 8, | .41 | 14.11 | 8, | .12 | 16.78 |
| 9, | .18 | 14.29 | 9, | .91 | 17.69 |
| 10, | .14 | 14.43 | 10, | .00 | 17.69 |
| 11, | .02 | 14.45 | 11, | .00 | 17.69 |
| 12, | .00 | 14.45 | 12, | .47 | 18.16 |
| 13, | .25 | 14.70 | 13, | .00 | 18.16 |
| 14, | .22 | 14.92 | 14, | .00 | 18.16 |
| 15, | .00 | 14.92 | 15, | .00 | 18.16 |
| 16, | .00 | 14.92 | 16, | .04 | 18.20 |
| 17, | .05 | 14.97 | 17, | .00 | 18.20 |
| 18, | .14 | 15.11 | 18, | .00 | 18.20 |
| 19, | .00 | 15.11 | 19, | .25 | 18.45 |
| 20, | .03 | 15.14 | 20, | .27 | 18.72 |
| 21, | .02 | 15.16 | 21, | 1.32 | 20.04 |
| 22, | .06 | 15.22 | 22, | .00 | 20.04 |
| 23, | .00 | 15.22 | 23, | .00 | 20.04 |
| 24, | .00 | 15.22 | 24, | .09 | 20.13 |
| 25, | .17 | 15.39 | 25, | .00 | 20.13 |
| 26, | .13 | 15.52 | 26, | .00 | 20.13 |
| 27, | .01 | 15.53 | 27, | .00 | 20.13 |
| 28, | .00 | 15.53 | 28, | .23 | 20.36 |
| 29, | .28 | 15.81 | 29, | .04 | 20.40 |
| 30, | .20 | 16.01 | 30, | .01 | 20.41 |
| 31, | .00 | 16.01 | 31, | .15 | 20.56 |

DAILY CUMULATIVE RAINFALL FOR THE YEAR 1904 (Cont.)

| DATE | DAILY PREC'N. | CUMULATIVE PREC'N. | DATE | DAILY PREC'N. | CUMULATIVE PREC'N. |
|---|---|---|---|---|---|
| SEPT. 1, | 1.25" | 21.81" | OCT. 1, | .01" | 25.20" |
| 2, | .89 | 22.70 | 2, | .00 | 25.20 |
| 3, | .07 | 22.77 | 3, | .10 | 25.30 |
| 4, | .00 | 22.77 | 4, | .27 | 25.57 |
| 5, | .00 | 22.77 | 5, | .00 | 25.57 |
| 6, | .04 | 22.81 | 6, | .00 | 25.57 |
| 7, | .00 | 22.81 | 7, | .80 | 26.37 |
| 8, | .07 | 22.88 | 8, | .49 | 26.86 |
| 9, | .00 | 22.88 | 9, | 1.74 | 28.60 |
| 10, | .00 | 22.88 | 10, | .19 | 28.79 |
| 11, | .00 | 22.88 | 11, | .02 | 28.81 |
| 12, | .00 | 22.88 | 12, | .02 | 28.83 |
| 13, | .27 | 23.15 | 13, | .00 | 28.83 |
| 14, | .03 | 23.18 | 14, | .00 | 28.83 |
| 15, | .00 | 23.18 | 15, | .00 | 28.83 |
| 16, | .00 | 23.18 | 16, | .00 | 28.83 |
| 17, | .00 | 23.18 | 17, | .00 | 28.83 |
| 18, | .00 | 23.18 | 18, | .18 | 29.01 |
| 19, | .02 | 23.20 | 19, | .52 | 29.53 |
| 20, | .00 | 23.20 | 20, | .95 | 30.48 |
| 21, | .00 | 23.20 | 21, | .11 | 30.59 |
| 22, | .00 | 23.20 | 22, | .01 | 30.60 |
| 23, | .52 | 23.72 | 23, | .00 | 30.60 |
| 24, | .78 | 24.50 | 24, | .07 | 30.67 |
| 25, | .06 | 24.56 | 25, | .06 | 30.73 |
| 26, | .00 | 24.56 | 26, | .05 | 30.78 |
| 27, | .04 | 24.60 | 27, | .00 | 30.78 |
| 28, | .59 | 25.19 | 28, | .00 | 30.78 |
| 29, | .00 | 25.19 | 29, | .00 | 30.78 |
| 30, | .00 | 25.19 | 30, | .00 | 30.78 |
| | | | 31 | .00 | 30.78 |

DAILY CUMULATIVE RAINFALL FOR THE YEAR1904 (Cont.)

| DATE | DAILY PREC'N. | CUMULATIVE PREC'N. | DATE | DAILY PREC'N. | CUMULATIVE PREC'N. |
|---|---|---|---|---|---|
| NOV. 1, | .00" | 30.78" | DEC. 1, | .00" | 30.95" |
| 2, | .00 | 30.78 | 2, | .00 | 30.95 |
| 3, | .00 | 30.78 | 3, | .04 | 30.99 |
| 4, | .00 | 30.78 | 4, | .00 | 30.99 |
| 5, | .00 | 30.78 | 5, | .00 | 30.99 |
| 6, | .00 | 30.78 | 6, | .00 | 30.99 |
| 7, | .00 | 30.78 | 7, | .00 | 30.99 |
| 8, | .00 | 30.78 | 8, | .01 | 31.00 |
| 9, | .00 | 30.78 | 9, | .05 | 31.05 |
| 10, | .03 | 30.81 | 10, | .06 | 31.11 |
| 11, | .00 | 30.81 | 11, | .16 | 31.27 |
| 12, | .00 | 30.81 | 12, | .11 | 31.38 |
| 13, | .00 | 30.81 | 13, | .00 | 31.38 |
| 14, | .00 | 30.81 | 14, | .00 | 31.38 |
| 15, | .00 | 30.81 | 15, | .00 | 31.38 |
| 16, | .00 | 30.81 | 16, | .00 | 31.38 |
| 17, | .00 | 30.81 | 17, | .00 | 31.38 |
| 18, | .00 | 30.81 | 18, | .08 | 31.46 |
| 19, | .00 | 30.81 | 19, | .09 | 31.55 |
| 20, | .00 | 30.81 | 20, | .10 | 31.65 |
| 21, | .07 | 30.88 | 21, | .05 | 31.70 |
| 22, | .00 | 30.88 | 22, | .01 | 31.73 |
| 23, | .00 | 30.88 | 23, | .02 | 31.75 |
| 24, | .00 | 30.88 | 24, | .00 | 31.75 |
| 25, | .00 | 30.88 | 25, | .00 | 31.75 |
| 26, | .01 | 30.89 | 26, | .21 | 31.96 |
| 27, | .00 | 30.89 | 27, | .12 | 32.08 |
| 28, | .01 | 30.90 | 28, | .70 | 32.78 |
| 29, | .05 | 30.95 | 29, | .00 | 32.78 |
| 30, | .00 | 30.95 | 30, | .00 | 32.78 |
| | | | 31, | .00 | 32.78 |

# APPENDIX "C"

## FLOOD FLOW DATA

### Year 1903

| RIVER | MAX. DISCHARGE IN SEC. FEET | DRAINAGE AREA SQUARE MILES | FLOW - SEC. FT./SQ.MILE |
|---|---|---|---|
| Chippewa | 51,750 | 6,740 | 7.7 |
| Flambeau | 10,800 | 2,120 | 5.1 |
| Black | 12,500 | 2,050 | 6.1 |
| Wisconsin | 13,000 | 3,100 | 4.2 |
| Wolf | 4,500 | 3,800 | 1.2 |
| Menominee | 10,500 | 1,800 | 6.3 |

### Year 1904

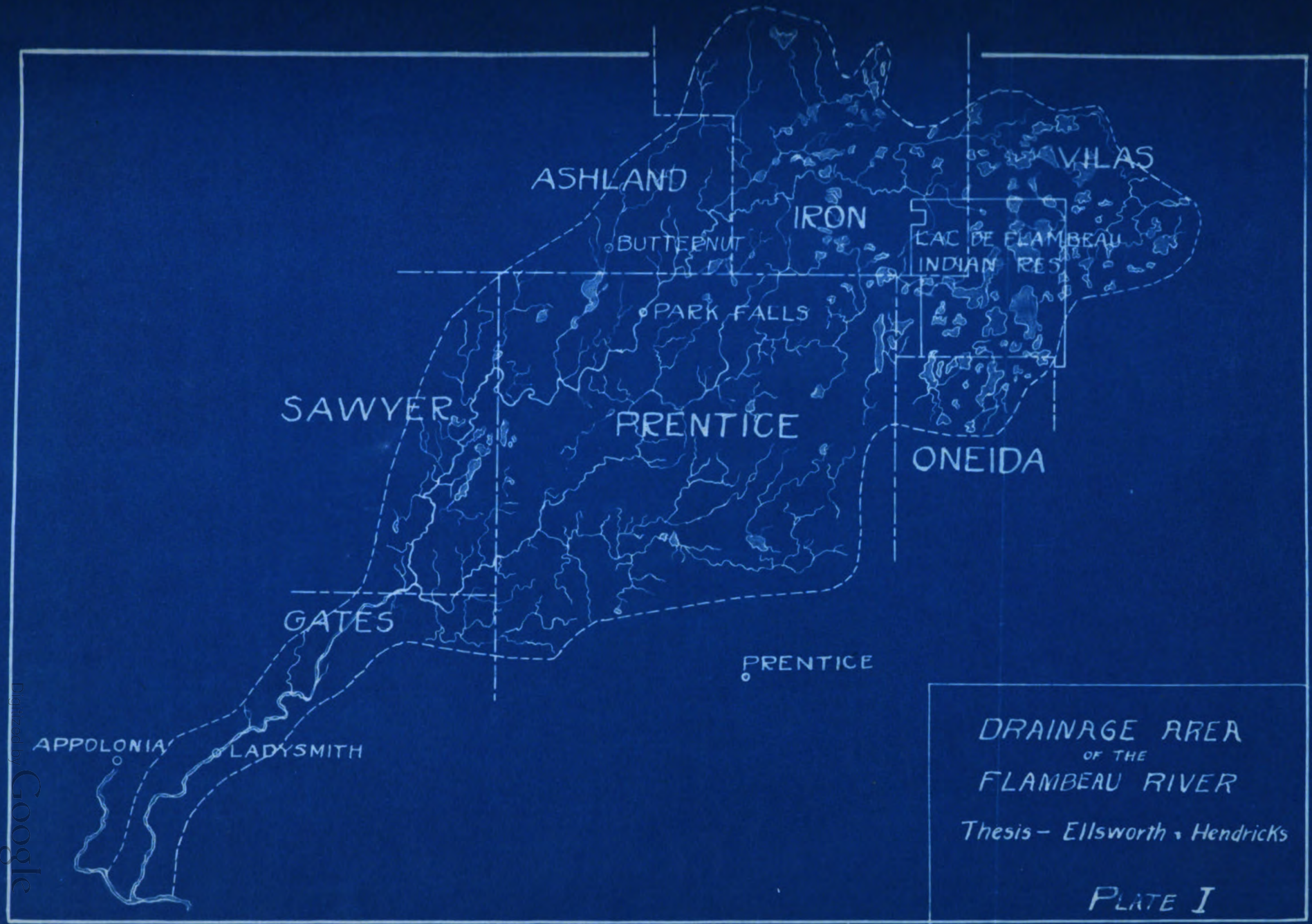
| | | | |
|---|---|---|---|
| Chippewa | 33,000 | 6,740 | 4.9 |
| Flambeau | 7,500 | 2,120 | 3.5 |
| Wisconsin | 18,000 | 3,100 | 5.8 |
| Menominee | 11,700 | 1,800 | 6.5 |

### Year 1905

| | | | |
|---|---|---|---|
| Chippewa | 23,000 | 6,740 | 3.4 |
| Flambeau | 8,400 | 2,120 | 4.0 |
| Black | 14,000 | 800 | 17.5 |
| Wisconsin | 13,500 | 3,100 | 4.4 |
| Wolf | 6,900 | 2,400 | 2.9 |
| Menominee | 9,500 | 1,800 | 5.3 |

| RIVER | MAX. DISCHARGE IN SEC. FEET | DRAINAGE AREA SQUARE MILES | FLOW - SEC. FT./ SQ. MI. |
|---|---|---|---|
| **Year 1906** | | | |
| Chippewa | 38,000 | 6,740 | 5.6 |
| Flambeau | 11,000 | 2,120 | 5.2 |
| Black | 5,000 | 800 | 6.3 |
| Wisconsin | 16,000 | 3,100 | 5.2 |
| Menominee | 14,000 | 1,800 | 7.7 |
| **Year 1907** | | | |
| Chippewa | 39,000 | 6,740 | 5.8 |
| Black | 8,700 | 800 | 10.9 |
| Wisconsin | 12,000 | 3,100 | 3.9 |
| Wolf | 2,500 | 970 | 2.6 |
| Menominee | 15,000 | 1,800 | 8.3 |
| **Year 1908** | | | |
| Chippewa | 30,000 | 6,740 | 4.5 |
| Black | 7,000 | 800 | 8.8 |
| Wisconsin | 13,500 | 3,100 | 4.3 |
| Wolf | 3,000 | 970 | 3.1 |
| Menominee | 12,000 | 1,800 | 6.7 |
| **Year 1909** | | | |
| Chippewa | 27,000 | 6,620 | 4.1 |
| Wisconsin | 12,000 | 3,100 | 3.9 |
| Menominee | 5,700 | 1,800 | 3.2 |

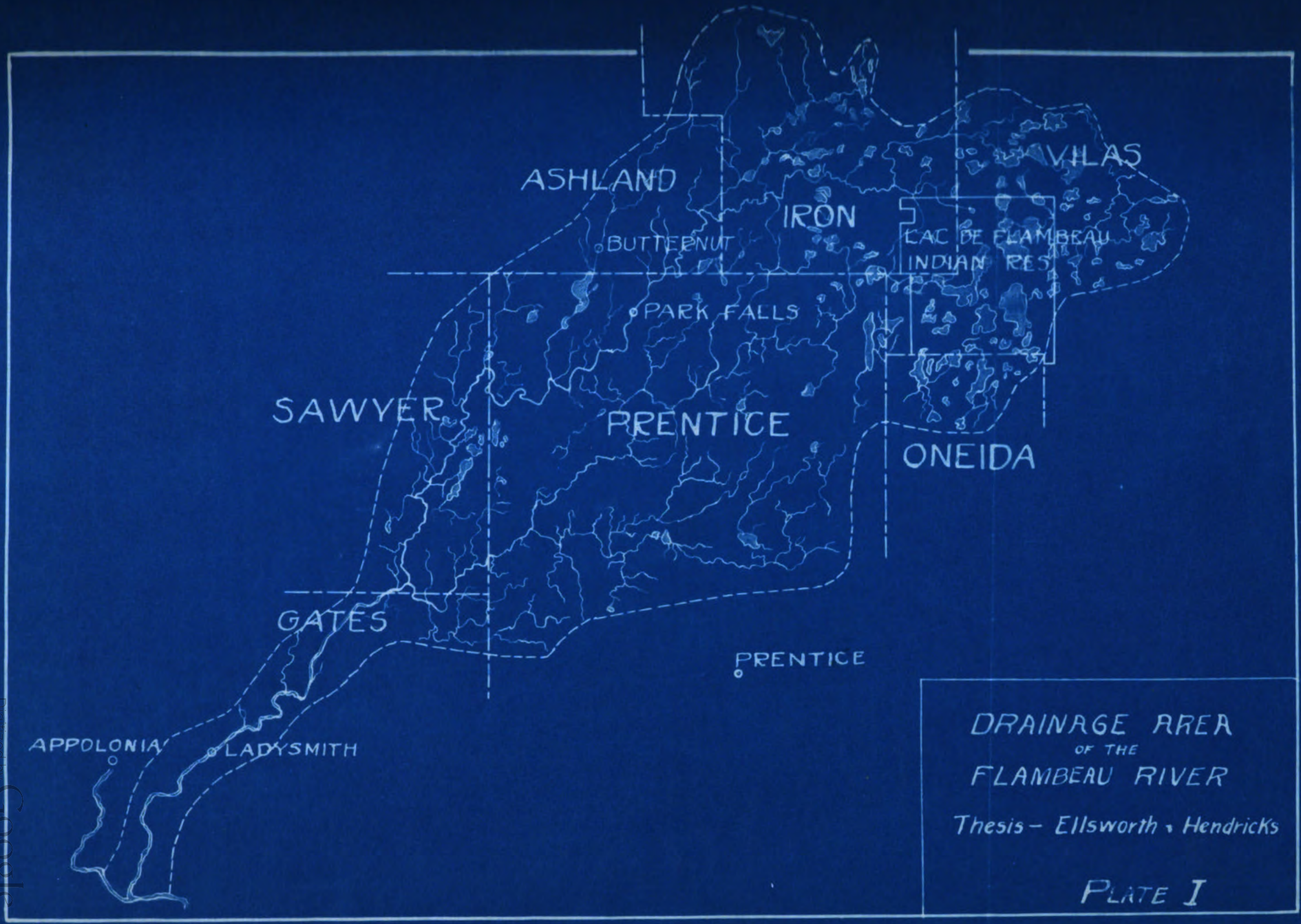
APPROVED:




DRAINAGE AREA
OF THE
FLAMBEAU RIVER

Thesis – Ellsworth & Hendricks

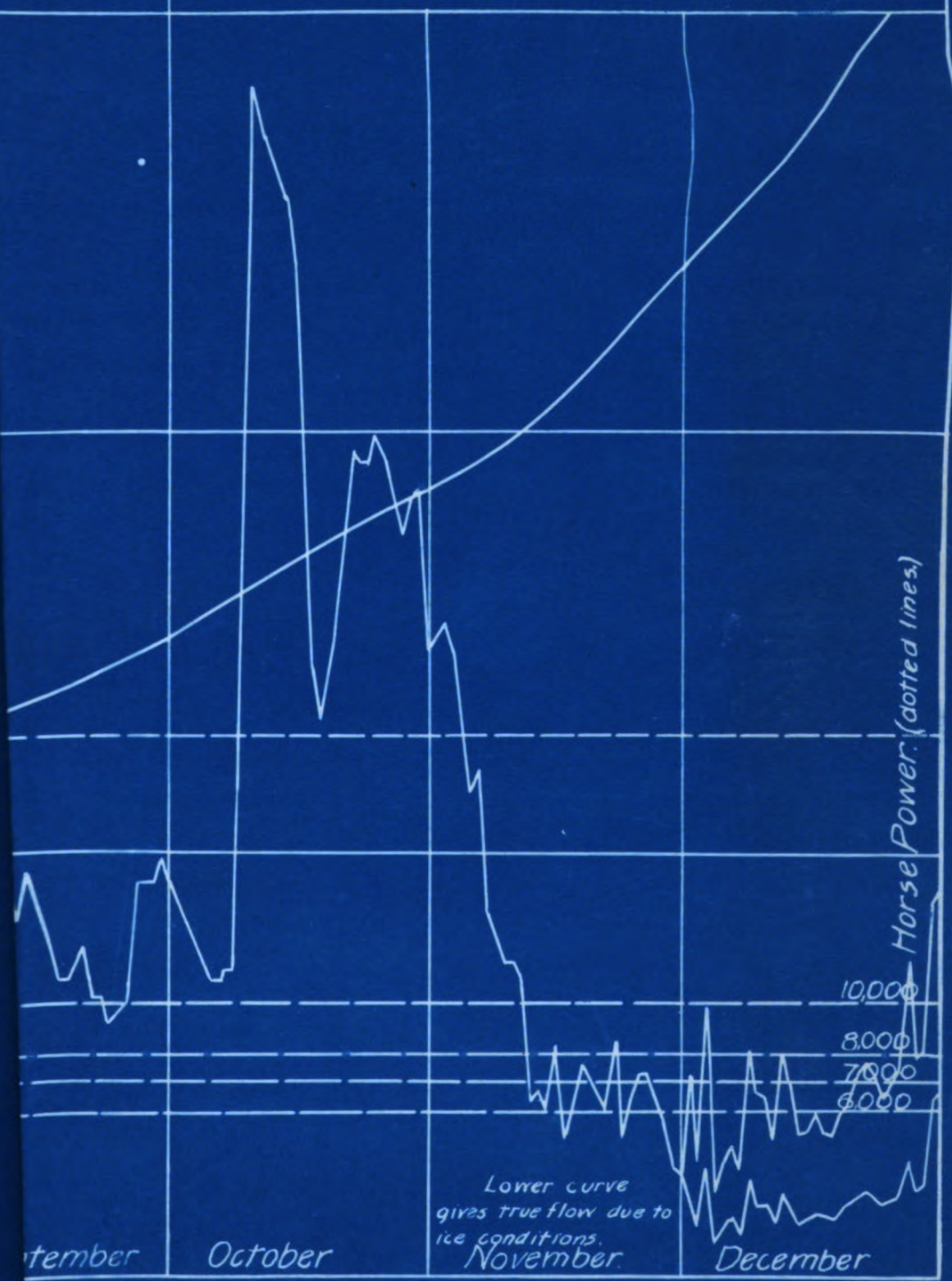
PLATE I

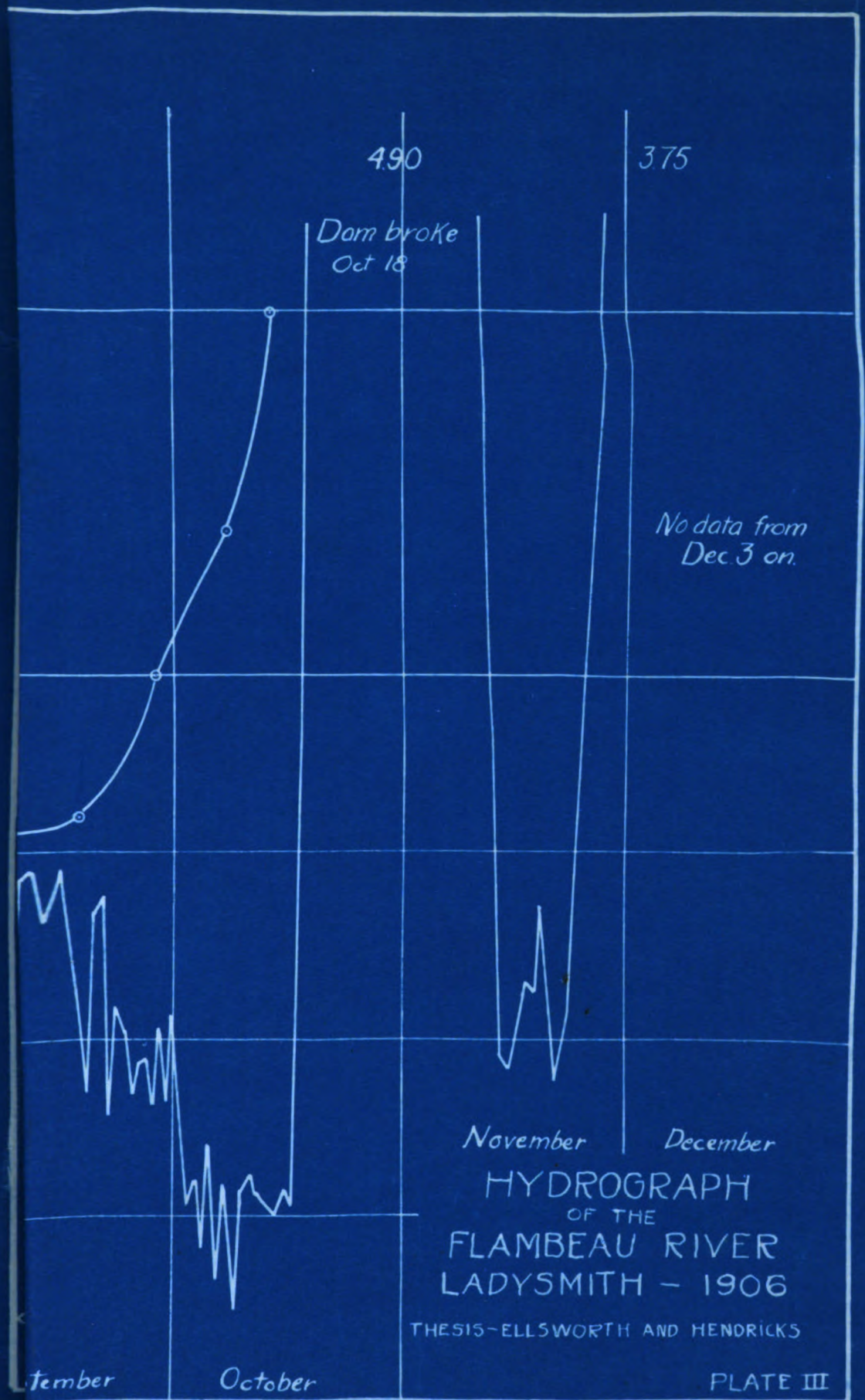


# HYDROGRAPH
OF THE
# FLAMBEAU RIVER AT LADYSMITH
1904

UNIVERSITY OF WISCONSIN.
THESIS — ELLSWORTH AND HENDRICKS

PLATE II





PLATES IV - VII

CURVES SHOWING AVERAGE MONTHLY RAINFALL

1889-1913